EFFECTS OF CONTINENTAL GLACIATION ON AGRICULTURE*

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3. Glacial Soils

(*a*) *Characteristics Distinguishing Glacial Soils from other Soils and their Agricultural Significance.* Glacial soils may be regarded as composed of a thorough mixture of mechanically derived material from many rock types, especially when they comprise a portion of the drift sheet resulting from continental glaciation. Such soils have been subject to solvent denudation only since their deposition by the glaciers, geologically a very short time. Residual, alluvial and other soils outside the glaciated areas, are, in contrast with the glacial soils, mostly accumulated as the result of chemical weathering and represent the relatively insoluble material of the rocks from which they are derived, or the stable secondary compounds formed during the processes of chemical weathering. Mechanical weathering has some part in the accumulation of a mantle of rock waste in non-glacial regions, but its influence is largely confined to the detachment and splitting up of larger rock fragments, which, by such processes, are made the more susceptible to complete disintegration and recombination later by chemical means. Thus non-glacial soils in humid, agricultural regions owe their characteristics primarily to the effects and results of chemical reactions on the bed rock from which they are derived. Under such conditions the relatively soluble materials of the bed rock are carried away while the resistant original minerals and the stable secondary compounds compose the soil particles.

To this contrast in origin—the glacial soils made up of mechanically derived detritus, a mixture of all the materials from many rock types, while the non-glacial soils are chemically derived insoluble residues—is commonly ascribed the greater average fertility, productiveness and value of the glacial soils. The conception is that the mechanically derived mixtures forming the glacial soils contain the mineral plant foods both in greater actual amount and in a more available form than do the weathering soils. Such data

* Concluded from the April *Bulletin*, pp. 241–264.

as are available[27] indicate that this is actually the case and probably accounts in part for the greater agricultural worth of the glacial soils. While a detailed discussion of this phase of the subject cannot be entered into here, it should be stated that it is maintained by some soil investigators that the capillary rise of water from subsoil and underlying bed rock, brings up more than enough of the soluble mineral plant food materials to compensate for the downward movement and leaching of such materials by the action of gravitational waters sinking through the larger soil pores during the relatively short periods of rainfall. If their contention is correct, textural variations in soils are more important than differences in the amounts of mineral plant foods present, as shown by chemical analyses, which latter do not necessarily indicate their availability for plants.

However, if the greater agricultural value of the glaciated lands were dependent on differences in soil composition alone, it would not be determined by merely chemical considerations. As has been shown above many other factors enter in to give the advantage agriculturally to the glaciated provinces. But, eliminating these for the moment, there are reasons, other than actual chemical make-up, inherently characteristic of the glacial soils themselves which may be cited to account for their greater productivity.

Local conditions of weathering and character of the bed rock are largely determinant of the nature of sedentary soils, both of their textural and chemical make-up. In consequence of this, where the country is alternately underlain by good and poor soil makers, the worth of the soils of the region will vary with them, and the phenomenon of fertile and relatively infertile soil in strips and bands is noted. This may be extreme, or only observable on careful examination. That this relation exists and may cause radical soil changes within short distances was clearly shown for an area in southeast England by Hall and Russell[28] of the Rothamstead Experiment Station. These authors also found that the Al_2O_3 of the clay in fertile soils had double the percentage solubility in the fertile as contrasted with the infertile soils, thus indicating that the differences were not wholly of a textural character. In glacial soils such rapid variations due to bed rock character do not occur. While a large percentage of the recognizable material in the de-

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27 von Engeln, O. D.: Some Factors Influencing the Percentages of Mineral Plant Foods Contained in Soils, *Amer. Journ. of Science*, Vol. XXXII, Nov., 1911, p. 350.

28 Hall, A. D. and Russell, E. J.: Soil Surveys and Soil Analyses, *Journ. of Agric. Science*, Vol. IV, Pt. 2, Oct., 1911.

posits from continental glaciers have been shown to be of local material,[29] this is not to be considered as local in any such restricted sense as in the case of the weathering soils, but local in that it represents largely a commingling of recognizable material from near adjacent areas. The finer material, the rock flour of glacial grinding, probably represents a much greater mixture of material, of which much is from distant sources. Plant growth, further, is much more influenced by the character and percentage of the fine material than by the coarser recognizable particles. In this matter of being a mixture, the glacial soils, therefore, resemble very closely alluvial bottom land or flood plain soils of the non-glacial regions, and these are proverbially fertile. Where, however, the glaciers passed over wide areas of rock, whose soil forming qualities are poor, the glacial soils also reflect in some degree the sterility which would mark soils derived from them by weathering processes.

The content of organic matter as determined by glacial action is another factor which must be recognized as contributing much to the reputed fertility of glacial soils. Thus almost all of the great prairie region of the Central West of the United States is covered by what has been termed the Marshall series of glacial soils.[30] They are characterized and distinguished from the Miami series of glacial soils by the relatively large quantity of organic matter in the surface soils, which gives them a dark brown or black color. These accumulations of organic matter may be ascribed to the very level character of the topography of these areas, due to the conditions of glacial deposit which resulted in poor natural drainage, and, consequently, of incomplete decomposition of the plant residues of their original vegetation cover. With artificial drainage, where necessary, these soils have become the great corn soils of the country and are very productive.

It is interesting to note also that, of the soil types of this series determined by texture, as well as of the other two great series of glacial soils, the Miami and Volusia, the loam, silt loam and clay loam types are noted as being the most valuable for general farm purposes, and that these are also the types which have by far the greatest acreage over the area so far surveyed.[31] Thus it is seen that the glacial soils possess distributional and compositional ad-

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29 Alden, W. C.: The Delavan Lobe of the Lake Michigan Glacier of the Wisconsin Stage of Glaciation and Associated Phenomena, *U. S. Geol. Surv. Prof. Paper 34*. 1904, pp. 86–87.

30 Whitney, Milton: Soils of the United States, *Bur. of Soils Bull. 55*, p. 144, U. S. Dept. of Agric., 1909.

31 Whitney, M.: *op. cit.*, pp. 144–147.

vantages, favorable to agriculture, other than that of simply greater initial content of mineral plant food.

(*b*) *Variation in Age of Glacial Soils with respect to Crop Productivity.* From what has been said above, it may be gathered that the geological youth of the glacial soils is a factor of importance in determining their superior agricultural worth. The original, undecomposed nature of the glacial soil particles, rock flour, and the short time they have been exposed to weathering processes are in part responsible for their so-called lasting and strong qualities in contrast with weaker, non-glacial soils. This distinction may be extended farther to include differences between the glacial soils themselves, according to the relative ages of the glaciations during which they were deposited. Thus Hopkins[32] has shown that, in the several glaciations which have, in the main, given rise to the soils found in Illinois, there is a progressive increase in the mineral plant food content of such soils from the oldest to the youngest. Moreover, a very real difference exists in the actual productivity of the soils of the early and late glaciations, whether or not this depends on the mineral plant foods present in them. Hubbard[33] shows this very strikingly by contrasting the agricultural conditions in the north-and-south adjacent Coles and Cumberland Counties of Illinois, the former lying almost wholly within the Early Wisconsin glaciation, while the latter has a Lower Illinoisan glaciation soil-cover over the greater part of its area. Land values in Coles County at the time the article was written ranged between \$75-\$125 per acre, with the average above \$75; while in Cumberland County (with the older Illinoisan glaciation soil-cover) the prices were between \$15-\$40 with the average near \$30. According to the 1910 census[34] average farm values in Coles County were \$125 per acre and over, while in Cumberland County they ranged between \$50 and \$75 per acre, yet in both counties 90-95% of the land was found to be in farms. According to Hubbard again, the value of crops, per acre of improved land, was from \$10-\$15 for Coles County and from \$6-\$10 for Cumberland County.

It may be that these differences in productivity should be ascribed to conditions of physiographic, rather than geologic youth and age, for in Coles County tile drainage is practiced, rich swamp

32 Hopkins, C. G., and Pettit, J. H.: The Fertility in Illinois Soils, *Univ. of Ill*, *Agric. Expt. Sta. Bull. 123*, pp. 201-202.

33 Hubbard, Geo. D.: A Case of Geographic Influence upon Human Affairs, *Bull Amer. Geogr. Soc.*, Vol. XXXVI, 1904, pp. 145-157.

34 *Bulletin Thirteenth Census of the United States, 1910: Agriculture, Illnois*, map p. 2.

lands are thus reclaimed, while in Cumberland County such drainage is useless, primarily because tributaries to main natural drainage streams are developed in so much greater numbers as to make the map of Cumberland County appear darker. Thus relative dissection of the glacial deposits themselves apparently makes for differences in crop productivity irrespective of differences in mineral plant food content. Leverett[35] makes clear the very strong contrasts in this respect which appear between the deposits of the different glaciations. "In the Illinoisan glacial drifts of western Illinois approximately one-half the surface has been reduced below the original level as a result of post-Illinoisan glaciation drainage development; while in the Wisconsin drift, post-Wisconsin drainage has scarcely sufficed to reduce one-tenth its original surface." In connection with such weathering and dissection the older glacial soils may have also undergone structural and textual modifications detrimental to fertility. As the youngest glaciations did not extend so far south and east in Central Europe as did the earlier ones it is possible that these glacial lands would show, if an exact comparison could be made, because of their greater age, an average lesser productiveness than do the younger glacial deposits which cover so large a part of the area of the central United States and southern Canada.

(*c*) *Textural Variations of Glacial Soils in relation to Diversified Agriculture.* In its broadest sense the term, intensive agriculture, implies the utilization both of the land and the labor of the man on the land to their utmost extent and according to the best methods and with the best equipment possible. Fulfillment of these conditions involves continual occupation for the labor on the farm. In order that this may be possible a variety of tasks to suit the different conditions of weather and season must be available; accordingly a variety of crops must be grown so that the work does not all come at once. In other words, diversified, as well as intensive agriculture, must be practiced to get the greatest possible economic advantage from the land. Even in regions where intensive agriculture, in the more restricted sense of specialization in one crop, is unprofitable, the opportunity for a diversified agriculture is important, for it means the possibility of producing a large proportion of the variety of foods demanded by the human and animal labor on the farm itself, where field crops are extensively raised for

[35] Leverett, F.: Weathering and Erosion as Time Measures, *Amer. Jour. of Science*, Vol. XXVII, 1909, pp. 356-7.

a money return. Therefore, if the soil over a large area is restricted, texturally and in other characteristics, to a very narrow variation in type, adapted to only a comparatively few crops, such uniformity in soil type is necessarily a detriment to both intensive and diversified farming. This is an economic disadvantage, as, with increasing density of population in civilized countries, a more and more intensive and diversified agriculture must be practiced.

According to present knowledge different plants are more adapted to textural variations than to variations in the other known characteristics of the soil. On the other hand this adaptation of plants to certain soils is often so marked that it has been proposed to classify soils according to their natural typical plant growth. Crops also are adapted to certain soils. A compilation made from a wide range of agricultural literature[36] showed that among others the following crops could be grown in largest quantity and in some cases also of best quality on the textural soil type indicated:

Clay—wheat, timothy, blue grass.
Silt loam—corn, apple.
Loam—red clover, alfalfa, field beans.
Sandy soils—potato, field peas, turnip, barley, rye, buckwheat, peach.
Calcareous soil—white clover.
Muck soils—celery, cabbage, lettuce, onions.

This list includes only such crops as show marked adaptation. It could be much extended if others were included that, other conditions being equally favorable, thrive best on certain soil types.

The application of the above paragraphs is found in the wide variety of conditions which attended the deposition of material by the ice during the retreat of the continental glaciers, giving rise to a great diversity in soil types. A list of the different forms of glacial deposit to which distinctive names have been given will almost suffice to show how wide the range in texture is. Often, moreover, these forms intergrade in a manner most puzzling to the glacial physiographer who attempts to map them, such combinations adding further complexity to the soil texture in the glaciated regions.

Conspicuously developed terminal, recessional and lateral moraines are commonly stony, with a filling of gritty clay between the boulders. Though large boulders may not predominate the materials composing their ridges are typically coarse, sandy and

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36 By Dr. Bouyoucos, formerly of the N. Y. State Agric. College at Cornell University, soil seminar, March 20, 1911.

gravelly, in general unfit for cultivation. In the central plains and prairie region of the United States such morainic masses are commonly given over to farm wood-lots and pasture land. Similarly the coarse stratified material of kames and eskers and their steep topography unfits them for the plow and they are generally timber-covered so that it is difficult to obtain good photographs showing the sinuosities of an esker course. Drumlin forms are equally steep but have better soils texturally; they are, therefore, generally under cultivation. Much more extensive in area over the glaciated regions than the conspicuous ridge deposits of moraine, kame, esker and drumlin, are the lower, more massive moraines, the ground moraine and the till sheet. These forms can not be sharply differentiated in the field. They grade into one another. In general they comprise the material deposited by the ice during periods of slow but essentially continuous melting back. Under such conditions the thin wedge at the front of the ice may be conceived of as fairly clogged with debris, super-, en- and subglacially, a concentration of all the stuff distributed through a much greater thickness of ice back from the front. Away from hilly and mountainous regions this material was probably mainly massed in the lower ice layers, the cargo acquired by erosion and abrasion in the long journey from the centers of ice dispersion. In regions of greater relief, where ridges and summits projected far up into the body of the ice currents, or even through them, in the waning stages, englacial and superglacial material amounted to a much greater bulk of the deposits laid down. Thus the till sheet (embracing in that general term the low massive moraines and the ground moraine) varies in composition from the thin bouldery deposits of the New England uplands (where it has been estimated that in some parts it took on the average a month's work for a man to remove the large stones from each acre to get it ready for plowing) to the deep, fine textured aggradations of the plains areas, derived from prevailing soft rocks, converted into rock flour by glacial grinding under the sole of the ice, and extending now practically level and unbroken over miles of area. Although such extremes in texture occur in these deposits of similar origin the till sheet on the whole supplies a prevailingly fine soil. Of the approximately 24,000,000 acres of area covered by such glacial material that have been mapped in the United States by soil surveys, about 73 per cent. has been found to come within the narrow textural range of loam, silt loam and clay loam. These are all heavy soils adapted to general farming, and they have been desig-

nated the great wheat and corn soils of the country.[37] The smaller areas of coarser, lighter soils, sandy in texture, associated with the loam soils, and part of the same deposits in origin, are well adapted to fruit and vegetable growing, though not yet utilized to their fullest extent. Thus while plenty of opportunity is afforded for variety of crops, the greater proportion of such lands is specially adapted to the growing of the two grains which are staple foods for man and beast.

The surface portions of the till sheet deposits no doubt owe their prevailingly fine texture in part to postglacial weathering, but, in part also, to the influence of outwash waters depositing fine particles between the larger morainic fragments. When the outflowing glacial waters were of greater volume and faster flow, coarser particles could be carried and deposited away from the ice front. Of such origin are the sand plains, outwash gravel aprons, glacial river terraces and valley trains. But associated with these coarser soils are found areas of very fine grained and dense lake clays, deposits in quiet waters of temporary or higher level lakes and ponds of the glacial period. These outwash and lake bottom soils have in general a lower topographic position than the other glacial material, consequently they are nearer the level of the underground water table. This often insures them a water supply where in other positions such coarser soils would drain and dry out too rapidly. Consequently a heavier type of crops can be grown on many of these soils than would otherwise be possible. The sorting action of water has further resulted in a separation of a much greater number of textural grades of soils than in the till-covered areas, and has arranged them in much more definite groups and bands. This combination of conditions gives a great opportunity for specialization in different crops within comparatively narrow areas. On the lake clays wheat, hay, oats and grapes thrive. The clay loams are available for intensive dairying, as they are unexcelled grass lands, and are also adapted to wheat. The loam group, including gravelly and stony loams, is perhaps the most typical of the soils of this region; such are very important for canning-vegetables, producing large yields of fine, firm quality. (Fig. 5.) These are also some of the best fruit soils, especially for apples and pears. Sugar beets and tobacco do well on the sandy loams, as do also peaches. The sandy soils are best for potatoes, strawberries and early vegetables.

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37 Whitney, M.: The Use of Soils East of the Great Plains Region, *Bur. of Soils Bull. No. 78*, pp. 95 and 129, U. S. Dept. of Agric.

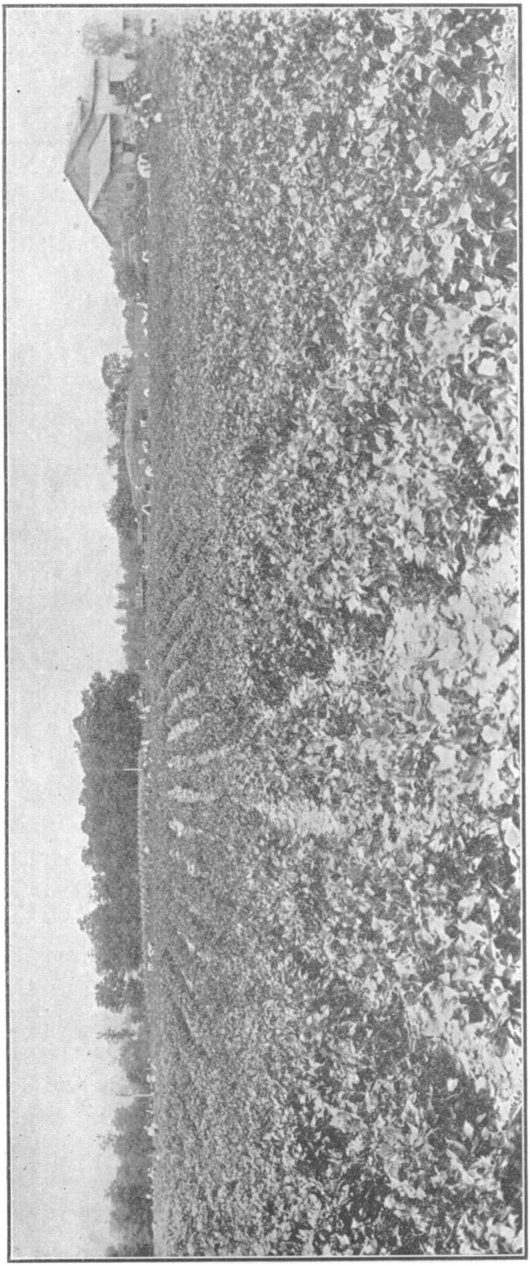

FIG. 5—Harvesting Field Beans from Broad Fields on Outwash Gravel Plain near Cortland, N. Y.

It would manifestly be impossible within the limits of this paper to consider this topic in full in its regional aspects. Several areas, however, have had their crop production so definitely determined by the typical sandy-gravelly nature of glacial outwash material as to merit special mention. In Maine, Ireland, Denmark and East Prussia glacial outwash features predominate, and on the sandy soils characteristic of such origin these regions produce potatoes in large quantities and in large yields per acre. To such a degree is this true that the dependence of the Irish and Germans on the potato for a chief food staple is proverbial. Latterly the sugar beet also has been very successfully grown on such soils, especially in Prussia. On the other hand, a large part (nearly one-sixth of the state) of the northern region of the southern peninsula of Michigan, comprising such sandy soils, formerly covered with great forests of white pine, have, since the complete cutting of the forest and the destruction of its humus floor, developed into infertile "pine barrens," at present practically worthless.

It would probably be difficult to demonstrate whether, on the whole, agriculturally similar regions within or without the glaciated areas have the more diversified soils. That the glacial soils, however, are sufficiently diversified in texture to afford possibilities for growing a wide range of products within narrow areal limits is clearly shown. Moreover, in the glaciated regions, the heavy soils, suitable for the heavy cereal crops, the staples of agriculture, predominate to a marked extent. As a matter of comparison it is, however, interesting to note that in the United States south of the glacial belt there are in the Coastal Plain Province highly diversified soils, mostly light in texture. Over the Piedmont Province the soil types are remarkably uniform, and this is true also of the soils of the limestone valleys of the Appalachians, as it is for the soils of the river flood plains. On the Appalachian plateau uplands and mountains the soils are more diversified, but of comparatively low agricultural value. Accordingly the valuable non-glacial soils in the United States east of the Mississippi seem to be predominatingly uniform in texture over large areas, though if all the different provinces are considered, a wide range in texture is encountered. On the other hand the soils of France are highly diversified in character within a comparatively small area.

(*d*) *Loessial Soils.* Although they are in general peripheral to the glaciated areas and have been included with the till sheet soils in the discussion of textural characteristics, the loessial soils de-

serve a special mention in this paper on account of their unique nature and high fertility. Their occurrence adjacent to the glaciated regions is probably due to wind transportation of the finer particles of material from wide areas of mud flats, alternately wet and dry, formed by slow-moving and aggrading waters from the glacier fronts; flowing in shallow floods during periods of melting and disappearing almost wholly at other times. Thus loess is spread over the valleys and adjacent uplands of northern France and Belgium, of central Germany, and, extending into Russia, forms the substratum of the famous *chernozem,* or black earth, region, which constitutes the great wheat growing section of that country, the areas that were invaded by the melting waters flowing away from the ice fronts. Similarly, in the United States the loess is found extending far to the south of the glaciated areas and bordering the Mississippi and Missouri Rivers, through whose basins enormous quantities of glacial waters must have flowed during the various stages of the ice advances and retreats.

In texture the loess is coarser than clay, but finer than the finest sand. Its origin in the humid agricultural areas adjacent to the glaciated areas is indicated by its mineral composition, which includes angular, undecomposed fragments of calcite, dolomite and feldspar, products of glacial grinding of a size available for wind transportation. Chemically the loessial soils are, therefore, very rich in lime and to this their great fertility when well watered may be, at least in part, ascribed as may also their enduring qualities. In the subhumid region of the United States it is the most valuable soil type. The loess-covered counties of eastern and southeastern Nebraska produce most of the corn, wheat, oats and alfalfa grown in the state and are the most fertile areas within its boundaries.

4. Effects on Agriculture due to Hydrographic Phenomena Resultant from Glaciation

(*a*) *Glacial Lakes and their Effects on Local Climates and Agriculture.* Areas invaded by the continental glaciers are significantly characterized by the large number of lakes and ponds which dot their surfaces. The typical glacial lake regions of Europe, Finland, southern Sweden and the Norwegian and Scottish fiords and lochs lie outside the agriculturally important areas and have, therefore, no important bearing on this discussion. Many of the larger bodies of water, notably the Great Lakes, of the glacial lake region of North America, however, lie well within the agricultural

province of the southern portion of the district. Over the whole district it has been computed that lake waters cover 16 per cent. of the surface[38] and this figure does not take account of many small lakes not represented on available maps. Therefore, since the larger lakes lie to the south, it is evident that an even larger percentage would need to be stated to express the relative extent of water and land within the agriculturally available portion of the district.

The importance of this as an effect of glaciation on agriculture is, from one standpoint, self-evident. If from 16 to 20 per cent. of the land is covered by water that much area is lost to crop production.

It does not follow, however, from this, that the total loss to agriculture may be measured by a similar percentage. It may even be true that the net result of the glacial creation of these lake basins represents a net agricultural gain, if transportation facilities are considered a factor. Certainly, also, their presence favorably influences the agriculture of the lands adjacent to them by modifying the climate and thus making possible the profitable production of crops which could otherwise not be successfully grown in the same latitude.

Where bodies of water of considerable area exist they exert an important equalizing effect on temperature. Water absorbs more heat, holds more heat, is warmed to greater depths, absorbs and radiates heat more slowly than land. Further, 50 per cent. of the insolation on water areas is used in evaporating water. This develops a moist blanket of air above and adjacent to the water surfaces that is less subject to marked temperature fluctuations than dry air. The total effect of these differences is to make summers cooler, winters warmer, to prolong the fall season and retard spring, and, also, to check sudden temperature changes in short time periods. This last is especially important in the northern belt of prevailing westerly winds with its alternation of cyclones and anticyclones, in which the glaciated regions are situated.

These effects are very clearly shown by a consideration of the climatic features of the state of Wisconsin as set forth in a bulletin recently published.[39] As a result of lake influence (and elevation difference) the length of the growing season, from the last killing frost in spring to the first killing frost in fall, averages 171 days for

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38 Bowman, I.: Forest Physiography, 1911, p. 564.

39 Whitson, A. R. and Baker, O. E.: The Climate of Wisconsin and its Relation to Agriculture, *Univ. of Wis. Agric. Expt. Sta. Bull. 223*, July, 1912, pp. 25–27, 44, 54, 64.

five stations along the Michigan shore, whereas for five interior stations at corresponding latitudes it averages only 130 days. As the altitude differences in Wisconsin are not great this relation may be ascribed primarily to the lake influence. The Lake Michigan shore section possesses the most equable climate of Wisconsin. Similarly, stations along the Lake Superior shore have an average growing season of 139 days, while those inland, though located farther south, average only 95 days; but here differences in elevation are probably more effective.

The long growing season and high mean summer temperature make tobacco production possible in the southeastern corner of the state, adjacent to Lake Michigan. Even more marked is the climatic influence of the lake on fruit raising. Thus the two Wisconsin peninsulas that project respectively into Lake Michigan and Lake Superior are now experiencing rapid horticultural development, producing apples, cherries, bush fruits, and even peaches. Inland, these crops are impossible or unsuccessful. In the case of the northern, Lake Superior peninsula, growers are warned that the planting of orchards more than three miles remote from the water influence must be regarded as an experiment. In the southern portion of the state, however, fruit growing has proved profitable in many inland areas where even a small lake, of which there are thousands, afforded local climatic protection.

While Wisconsin undoubtedly derives great agricultural benefit from the effect of the glacial lakes on her climate, yet the state is at a disadvantage in that it lies to the windward of the large bodies of water, Lakes Michigan and Superior. Michigan, New York and Ontario derive similar benefits in more marked degree because they lie to the east and south of adjacent large lakes. The southern peninsula of Michigan is peculiarly favored in that it lies between two large bodies of water, Lakes Michigan and Huron (Fig. 6). Here peaches are regularly ripened on a parallel that forms the northern boundary of Vermont. The climate over the whole area of Michigan is insular to a marked degree.[40]

In New York the areas to the south and east of Lakes Erie and Ontario constitute distinct, wide, climatic provinces[41] with longer growing seasons than more southerly parts of the state, and constitute the great apple, grape and nursery growing areas for which

40 Schneider, C. F., Michigan, in "Climatology of the United States", *Weather Bureau Bull.1*, p. 556, U. S. Dept. of Agric.

41 Wilson, W. M.: Frosts in New York, *Cornell Univ. Agric Expt. Sta. of the College of Agric. Bull. 316*, p. 532, June, 1912.

the state is famous. In more restricted areas, adjacent to the narrow Finger Lakes of Central New York, the same climatic relations make possible the very successful growing of grapes. The province of Ontario owes in large part its great productiveness for general farming, nursery and fruit growing to the favorable influence of Lake Ontario on its climate. Fully 75 per cent. of all the fruit grown in Canada is produced in the peninsular Niagara district and in the southern part of the province of Ontario.

It must not be understood that, because the horticultural aspect

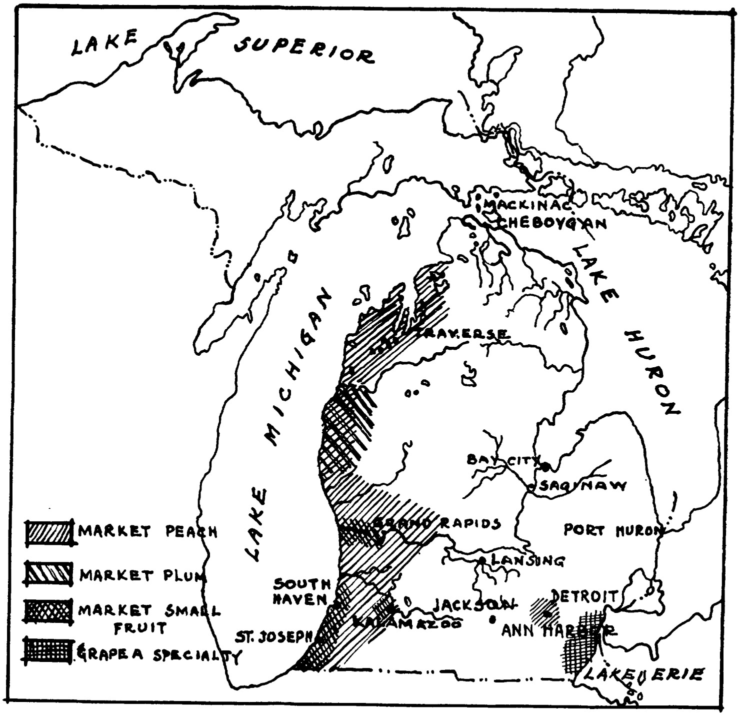

FIG. 6—Distribution of Fruit Crops in Southern Michigan. After W. W. Tracy in "Cyclopedia of American Horticulture," L. H. Bailey, Editor.

is emphasized in this discussion, fruit growing is the only phase of agriculture to which these lake districts are adapted. On the contrary, they produce abundant yields of many other crops. Fruit growing is, however, ordinarily, a precarious enterprise because of the great damage resulting from late or early frosts. For this reason it yields large profits in northern regions where the harvests can be depended on. Therefore, the agricultural value of these lands is

much increased by the equalizing influence of the glacial lakes on climate. Since unseasonable frosts damage other crops as well as fruit, the climatic conditions for these are made more favorable also, and where the modifying factor may not be great enough to protect fruit it may serve to save, in many instances, the hardier crops.

(*b*) *Agricultural Relations of Deposits in Drained and Filled Lake Basins.* The Great Lakes and their forerunners, the proglacial lakes margining the ice on its retreat, formerly extended over much larger areas than they do at present. Thus many acres of land surface in the glaciated area of North America (and also of Europe) are covered with deposits laid down in these lakes. In addition to such extensions of present lakes, there were also large areas, temporarily occupied by lake waters during the retreat of the ice, which were drained, after the ice barrier that prevented drainage to the northward, had melted away. Of these, the former Lake Agassiz, in the basin of the Red River of the North (North Dakota, Minnesota and Manitoba) is the most notable. Further innumerable smaller lakes and ponds that existed at the close of the glacial period have since been filled or drained by natural processes; in addition to the many others that have been reclaimed by drainage operations. In Minnesota it is said that there are 8,000 lakes large and small, and that one-half of these will be destroyed by natural processes within the next fifty years. Similarly in Connecticut of an estimated number of 4,000 lakes that existed after the glacial period some 2,500 have been obliterated.[42]

On the bottoms of these former lakes various kinds of deposits accumulated. While the ice was withdrawing and immediately after its withdrawal, streams flowing into such lakes carried large quantities of sediment, because the freshly accumulated glacial deposits lacked a vegetation cover and were easily eroded, and because great quantities of material were brought by streams outflowing from the ice itself. Therefore, in shallow bodies of water in which currents were readily set up, clays and silts were deposited often over large areas. The effects of this, as bearing on agriculture, was twofold. The previously existing lake bottom topography was leveled up, since the fine grained material tended to accumulate in hollows, because the water was more quiet in these, and because material which settled on slopes occupied unstable positions and tended to slump. This latter effect has been observed by the

42 Salisbury, Barrows and Tower: Elements of Geography, New York, 1912, p. 400.

writer in recently drained glacial lakes in Alaska, and is also apparent on the slopes of deeper lakes in the regions invaded by the continental glaciers whose hollows were not completely filled before the water was drained off. On the bottoms of the shallower lakes perfectly level plains were developed in this manner. The material deposited was thick, of fine texture, and, except for an occasional erratic dropped by a drifting iceberg, absolutely free of stones. The effects of postglacial weathering and of accumulation of humus from material plant growth, with consequent development of friability, on the surface layers of such deposits, resulted in the creation of a soil of extraordinary agricultural utility.

The floor of former Lake Agassiz previously mentioned, extending over an area of 110,000 square miles (larger than that covered by all the present Great Lakes) is of this character. Much of its expanse is as level as the surface of a calm sea. Furrows miles long may be plowed in deep, rich soil, producing a fine grade of hard wheat. Since 1870, and even now, this region is being developed by a great surge of farming people, attracted from all parts of the United States by its exceptional agricultural possibilities.

The levelness, depth and uniform texture of this soil makes it susceptible of cultivation by machinery on a large scale. As a result of this, and, also, because of the only slightly lesser adaptation of the level glacial till plains to such machine cultivation, the labor cost of grain production has been greatly decreased in modern times. Though areas outside the glaciated regions also offer opportunities for the use of labor saving machines in agricultural operations, yet the glaciated regions, inasmuch as they are the grain producing sections of the northern hemisphere, are largely to be credited for having effected this saving in the cost of our food supply. How much this saving in labor costs amounts to is not generally appreciated. Between 1858 and 1894 the total labor cost of producing a bushel of corn was reduced from 41 cents to 17 cents by this means. Similarly between 1830 and 1896 the total labor cost of producing a bushel of wheat was reduced from 20 cents to less than 6 cents.[43] This increased effectiveness of labor, made possible in large part by the level topography and depth of glacial soils, especially those on glacial lake plains, means a greater food supply at the same cost to offset the rise in population num-

[43] Holmes, G. K.: Agricultural Production and Prices, *U. S. Dept. of Agric. Year Book, 1897*, pp. 600-601. This paper contains many other similar interesting schedules for various crops.

bers, as the soil can be cultivated more intensively, with higher returns per acre, without the necessity of increasing the number of individuals engaged in agriculture.

On the more porous, well-drained soils, margining the former extension of the Great Lakes, are located in large part the fruit growing areas noted in the paragraphs on climatic relations. These areas represent the beaches and wave-worked material along the former shores.

The smaller lake areas were more commonly filled by vegetation growth. This applies also to lakes and ponds which have been reclaimed by man. These smaller basins are almost all morainic hollows or dammed river valleys. Their drainage basins are relatively small, consequently no great amount of sediment was poured into them immediately after the glacial period. As they often constitute relatively deep pockets with no outlets they are characteristically susceptible to late and early frosts, because cold air, as it forms on the slopes, slides down and accumulates in such hollows. Furthermore, the thick covering of marsh grasses that naturally cloaks their level swampy surfaces prevents the sun's heat from getting to and warming the soil.

While such vegetation-filled, glacial lakes, when drained, have, as a rule, deep rich, black muck soils, this is not always the case. Frequently the organic deposits have not decomposed to the humus stage, are peaty in character, acid and deficient in mineral elements. To make such land available for agriculture requires application of lime. An interesting coincidence is that deposits of lime, in the shape of marl, often occur on the borders or under the vegetable deposits of such lakes and are thus most conveniently available for use on the area.

When skillfully treated such reclaimed muck lands yield most abundant returns in truck crops. Many of the most productive market gardens around the cities of the glaciated regions are on such soils. As instances, those around Chicago, Detroit and Port Huron may be cited. Celery, especially, is an extremely profitable crop on such lands, because it is a truck crop that may be stored and shipped to distant markets. Thousands of acres of these vegetation-filled lake basins still remain to be reclaimed. Because they have not yet been utilized the presence of these areas is not to be considered as a detrimental result of glaciation on agriculture. What they may be worth in the future is well illustrated by the data of one little reclamation project in central New York at Spencer Summit, south of Ithaca. Here 103 acres of marsh land,

a filled morainic lake basin, were purchased at a cost of $10.00 per acre. At a total expenditure of $3,100 this land was drained. A large portion of it was found to be underlain by marl. At an expenditure of about $11 per week it can be kept drained.[44] Celery, onions and lettuce will be grown. Similar land near Rochester, N. Y., is valued at from $300 to $1,000 per acre. Planted to celery this land will yield returns justifying its valuation at $245 per acre. Thus, by an expenditure of some $3,000, land worth $1,030 has been raised in value to $25,000. While this extraordinary increase is in part due to favorable location, with respect to shipping facilities, and to the low cost of the drainage operations, there is no doubt that a relatively great rise in land value will result from the drainage of many thousands of similar areas, still unreclaimed.

5. Summary

(*a*) Comparisons of the agricultural status of adjacent regions within and without the glaciated regions, whether between broad areas or smaller next adjacent sections, show a consistently higher development in the glaciated regions of dominant drift accumulation.

(*b*) Regions of predominant glacial erosion, whose agricultural value was impaired by such action, are climatically or topographically unfit for agricultural development of high order. They are best adapted for a forest crop, and for this sufficient soil remained or has accumulated since glaciation.

(*c*) In regions of very diverse rock structure, along contact lines of igneous and sedimentary rocks and in regions of bold relief, ice erosion resulted in a steepening of valley slopes and the carving of rock basins, giving rise to lakes. The steepened slopes are generally not cultivable, but as a rule support forest growth. They are, also, a detriment to agricultural transportation. In large measure such steepening of valley slopes is, however, compensated for by erosional widening and drift-deposit leveling of valley floors. The formation of lake basins, on the other hand, made large areas unavailable for agriculture. The irregular topography and in some instances the stony material of well-developed morainic ridges are adverse to their agricultural use, as is also the poor air drainage of the intervening hollows. Moraines and other

44 Data from man in charge.

drift deposits of such strong expression are not, however, of great areal extent.

(*d*) The extensive leveling, both by glacial erosion and drift deposit, of the minor rugosities characteristic of the normal, mature stage of development of preglacial relief constitutes an extremely favorable influence on agriculture resultant from ice invasion. Flat, upland, interstream areas may in some instances have suffered by modification of relief, in that their residual soils were eroded and only thin, stony soils left in their place by the ice.

(*e*) The average great thickness of the drift deposits and their level topography conserve the ground water supply of the glaciated regions.

(*f*) Glacial soils are more fertile than non-glacial soils; in part because they contain a higher percentage of the soluble mineral plant foods. Great commingling of different rock materials in glacial soils gives more uniform composition and fertility to them than is characteristic of sedentary soils. The level topography of glacial drift plains soils resulted in a deep accumulation of organic matter, which contributes much to their agricultural worth. The dominant textural quality of glacial soils is that best adapted to the production of the staple food crops.

(*g*) The deposits of the younger glaciations which cover the larger part of the ice invaded regions of central North America have a greater crop productivity than the older glacial soils.

(*h*) Owing to the wide variety of conditions attending the deposition of glacial drift, many textural soil types occur in the glaciated regions, providing for diversified and intensive farming within narrow areal limits. The more valuable non-glacial soils are quite apt to be uniform in texture over wide areas.

(*i*) Loessial soils extend the favorable influence on agriculture, due to glaciation, beyond the limits of the ice advances. Some of the non-glaciated areas would probably show even more marked agricultural deficiency, as compared with the glaciated regions, if these loessial soils were not present.

(*j*) In the humid agricultural section of eastern North America from 16 to 20 per cent. of the glaciated areas is unavailable for agriculture because submerged under glacial lake waters. This loss is offset, perhaps in very large measure, by the modifying in-

fluence of such bodies of water on climate. This climatic protection especially favors the production of valuable fruit crops.

(*k*) The level topography, uniform soil texture, the deep humus cover, and often the great areal extent of deposits on drained and filled glacial lake basins affords a soil of great fertility and very susceptible to cultivation by mechanical power. By such utilization of machinery on these areas and, also, on the level till plains, the labor cost of grain production has been very materially reduced. In conjunction with the muck deposits, characteristic of the filled basins of the smaller glacial lakes, are often found marl deposits. These may be used to advantage to correct possible acidity in the muck, in which very profitable crops of vegetables may then be grown.

6. Conclusions

The beneficial effects on agriculture, due to glaciation, are of wide variety and apparently outweigh detrimental influences due to the same cause. As a net result, glaciated lands are, therefore, of greater agricultural value and utility than non-glaciated areas under otherwise essentially similar conditions. It is not feasible, however, to state numerically the order of this difference, because too many unwarranted assumptions would need to be made.